INDOOR AIR QUALITY ASSESSMENT

Leominster Highway Department
109 Graham Street
Leominster, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
September 2006

Background/Introduction

At the request of Christopher Knuth, Director of the Leominster Board of Health, an indoor air quality assessment was conducted at the Leominster Department of Public Works (LDPW), 109 Graham Street, Leominster, Massachusetts. On January 27, 2006, a visit to made to the LDPW by Michael Feeney, Director of the Massachusetts Department of Public Health's (MDPH), Center for Environmental Health (CEH), Emergency Response/Indoor Air Quality (ER/IAQ) Program. The assessment was prompted by concerns related to lack of ventilation for the garage repair shop.

The LDPW is a cinderblock aluminum-sided structure that was built in the 1980s. The facility consists of a repair shop, multiple garage bays (Picture 1), garage, a large truck parking garage, office space, locker room and kitchen/break room. Windows in the offices are openable.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520.

Results

The LDPW has an employee population of approximately 15 and can be visited by up to 10 members of the public on a daily basis. The tests were taken under normal operating conditions. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million (ppm) parts of air in most areas surveyed, indicating adequate air exchange. Mechanical ventilation is provided by a heating, ventilating and air conditioning (HVAC) system. A wall air-handling unit (AHU) introduces fresh outdoor air to the offices (Picture 2). Conditioned outside air is distributed through ducted ceiling-mounted supply vents and returned to the AHUs by ducted ceiling-mounted return vents.

A free standing structure in the garage functions as the break room (Picture 3). This room has no mechanical ventilation system. Ventilation is provided by open doors in the garage.

Local mechanical exhaust ventilation systems are installed in the garage ceiling (Picture 4) and repair shop (Picture 5) to remove airborne pollutants (e.g., odors, fumes, carbon monoxide and other products of combustion) from the garage and repair shop. The systems are described in detail under the Specialized Local Exhaust portion of this report.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical ventilation system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 20 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature readings in occupant areas were measured in a range of 65° F to 72° F, which in most cases were slightly below the lower end of the MDPH recommended comfort range. The lowest temperature (59° F), was measured in the garage, where bay doors frequently open and close. The MDPH recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

Relative humidity measurements ranged from 16 to 28 percent, which were below the MDPH recommended comfort guidelines. The MDPH recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. Relative humidity would be expected to drop below comfort levels during the heating season. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Of note was a humidifier in the office space, which appears to be antiquated. This humidifier model has a rotating wheel with sponges attached along the edge. As the wheel rotates, the sponges are dipped into a water reservoir. An air stream directed at the wet sponge aerosolizes water vapor. The water reservoir and filter can become prone to accumulation of biofilm. Biofilm is produced by microorganisms. The configuration of this humidifier makes frequent cleaning difficult, thus rendering it prone to microbial growth. According to staff, this humidifier has been in use for at least 20 years. It is likely that the use of this humidifier would aerosolize microorganisms and odors. In general, humidifiers should be cleaned frequently in a manner consistent with manufacturer's instructions. Failure to do so can make a humidifier a source and distribution medium for microbial growth (US EPA, 1991).

One area had water-stained ceiling tiles. Water-damaged ceiling tiles can provide a source for mold growth and should be replaced after a moisture source or leak is discovered and repaired. Missing and/or damaged tiles can provide a means for dust and particulates that accumulate in the ceiling plenum to move to occupied areas. If porous materials become wet repeatedly they can provide a medium for mold growth. The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommend that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur.

Specialized Local Exhaust

Repair Garage

During the assessment, CEH staff observed welding in the repair shop. Exhaust ventilation equipment exists in this space, but was *not* used during welding (Picture 6). The repair shop also has a ceiling exhaust fan, which also was *not* operating during this assessment. Exposure to welding fumes is associated with a number of health effects. "Acute exposure to welding fumes can result in eye, nose, and throat irritation, fever, chills, headache, nausea, shortness of breath, muscle pain, and a metallic taste in the mouth. Chronic exposure to welding fumes can result in respiratory effects including coughing, wheezing, and decreased pulmonary function" (OSHA, unknown). The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) for welding fumes (and total particulates) of the "lowest feasible concentration," since NIOSH considers welding fumes potential occupational carcinogens (NIOSH 1992). For this reason, exhaust ventilation for welding operations should be designed in a manner to draw fumes away from the welder. The repair garage welding exhaust ventilation system did not appear to be equipped with flexible ducts of adequate length to provide an adequate means to draw welding pollutants away from the operator. To reduce exposure, a flexible hose connected to a fume venting system should be placed in a location opposite the operator and point of welding. Refer to Appendix B for additional information concerning welding occupational safety.

Main Garage and Offices

Under normal conditions, a garage/public works facility can have several sources of environmental pollutants present from the operation of vehicles. These sources of pollutants can include:

- Vehicle exhaust containing carbon monoxide and soot;
- Vapors from diesel fuel, motor oil and other vehicle liquids which contain volatile organic compounds (VOCs);
- Water vapor from vehicle washing equipment; and
- Rubber odors from new vehicle tires.

Of particular importance is vehicle exhaust. In order to assess whether contaminants generated by vehicles were migrating into occupied areas of the LDPW, measurements for airborne particulates in combination with carbon monoxide were taken. These measurements were used to identify sources of combustion products.

Of the materials produced by the process of combustion, carbon monoxide can produce immediate, acute health effects upon exposure. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within the rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The US Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide in outdoor air. Carbon monoxide levels in outdoor air must be maintained below 9 ppm over a twenty-four hour period in order to meet this standard (US EPA, 2000). *Carbon monoxide should not be* *present in a typical, indoor environment.* If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide measurements were non-detect or ND. Carbon monoxide levels measured in the LDPW office areas were ND, while a measurement of 3 ppm was detected in the repair garage (Table 1). The most likely source of CO in the repair garage was the operation of vehicles in the garage.

The use of fossil fuel-powered equipment (propane heaters, diesel or gasoline-powered vehicles, acetylene welding, etc.) can produce carbon monoxide. Using a carbon monoxide monitor as the sole use of detecting sources of combustion pollutants has a major drawback. If the source of combustion pollutants is allowed to dilute in a large volume of air within a building, carbon monoxide concentrations may decrease below the detection limits of equipment. The process of combustion also produces airborne liquids, solids and gases (NFPA, 1997). The measurement of airborne particulates, in combination with carbon monoxide measurements can be used to identify the source of combustion products.

The combustion of fossil fuels can also produce particulate matter that is of a small diameter (10 μm) which can penetrate into the lungs and subsequently cause irritation. For this reason, a device that can measure particles of a diameter of 10 μm or less was also used to identify pollutant pathways from vehicles into the occupied areas. Inhaled particles can cause respiratory irritation.

The US EPA also established NAAQS for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000). This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particulate levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 9 $\mu g/m^3$ (Table 1). PM2.5 levels measured in occupant areas ranged from 9 to 39 $\mu g/m^3$, which were below the NAAQS PM2.5 level of 65 $\mu g/m^3$ in all office areas. In the garage area, including the break room, PM2.5 levels measured indoors ranged from 218 to 498 $\mu g/m^3$ (Table 1). Vehicle operation and/or activities (e.g., arc welding) can generate particulate matter during normal operations.

Several potential pathways for exhaust emissions and other pollutants to migrate into occupied areas were identified. The doors to the offices had spaces beneath the door where light could be seen penetrating. The ceiling/walls of the garage and offices are penetrated by holes for utilities or roof trusses (Pictures 7 to 9). If they are not airtight, these holes can serve as potential pathways for particles to migrate into occupied areas. Each of these conditions presents a pathway for air to move from the garage to adjacent areas. In order to explain how these pollutants may be impacting adjacent areas, the following concepts concerning heated air and creation of air movement must be understood.

- Heated air will create upward air movement, a condition known as the stack effect.
- Cold air moves to hot air, which creates drafts.
- Negative pressure is created as heated air rises. This pressure in turn draws cold air to the equipment creating heat (e.g., vehicle engines).
- Combusted fossil fuels contain heat, gases and particulates that will rise in air. In addition, the more heated air becomes the greater airflow increases.
- Negative air pressure created while HVAC systems (including rest room exhaust vents) are operating can draw air and pollutants from the garage and mechanics' bay.

Each of these concepts has influence on the movement of airborne pollutants to adjacent areas. As motor vehicles operate indoors, the production of vehicle exhaust in combination with cold air moving from outdoors through open exterior doors into the warmer garage and mechanics' bay can place them under positive pressure. Positive pressure within a room will force air and pollutants through spaces around doors, utility pipes and other holes in walls, doors and ceilings. To reduce airflow into adjacent areas, sealing of these pollutant pathways should be considered.

The LDPW is equipped with a ceiling-mounted mechanical exhaust system to remove exhaust emissions and other pollutants from the building. Ceiling exhaust fans can mix and draw vehicle exhaust upwards. This mixing phenomenon provides the potential for vehicle exhaust to penetrate office areas through the holes and spaces noted in the office walls. A more effective method of exhaust ventilation would be to locate exhaust fans in the wall next to the parked vehicles, to draw exhaust away from the offices and break room.

Other Concerns

An ozone generator was observed in the office area. At this time, the efficacy of ozone as an indoor air cleaner is being examined by several government agencies. While ozone may be effective in removing some odors of biological origin (e.g. skunk), its use as a universal air cleaner has not been established (US EPA, 2003). As discussed, ozone is a highly irritating substance to the respiratory system. Until more definitive information becomes available, the use of ozone generators in occupied areas should be done with caution.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Repair the exhaust ventilation system for welding activities in the repair shop.
2. Consider consulting with an industrial hygienist for the best methods to provide exhaust ventilation for welding operations in the repair shop.
3. Consider installing exhaust fans in the wall along the parking area for LDPW vehicles. Use of these fans would necessitate having vehicles the back into spaces to effectively draw vehicle exhaust outdoors.
4. Contact an HVAC engineering firm for possible solutions (e.g., roof) for providing outside make up air for the mechanic’s bay. Continue to operate local exhaust system in mechanics’ bay during hours of occupation. Due to the type of materials used (e.g., solvents, paints, fuels), consider installing an automatic timer to operate the system continuously during occupied hours.
5. Keep all office doors accessing the garage closed at all times.

6. Ensure office doors around the garage fit completely flush with threshold. Seal doors on all sides with foam tape, and/or weather-stripping. Consider installing weather-stripping/door sweeps on both sides of doors with access to the engine bay to provide a duel barrier. Ensure tightness of doors by monitoring for light penetration and drafts around doorframes.
7. Examine the feasibility of installing a mechanical ventilation system for the break room.
8. Identify and seal any utility holes in the shared walls of the office and garage and their terminus to reduce/eliminate pollutant paths of migration.
9. Continue to change filters for HVAC equipment as per the manufacturer's instructions or more frequently if needed.
10. Operate both supply and exhaust ventilation continuously during periods of building occupancy independent of thermostat control to maximize air exchange. Consider setting thermostat controls to the "on" position to provide constant supply and exhaust ventilation.
11. Consider having ventilation systems re-balanced every five years by an HVAC engineering firm.
12. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water

during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

13. Repair/replace any remaining water-stained, missing or damaged ceiling tiles. Examine areas above these tiles for microbial growth. Disinfect with an appropriate antimicrobial where necessary.
14. Discard humidifier in office
15. Discontinue use of ozone generator in office areas.
16. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website: http://www.state.ma.us/dph/CEH/iaq/iaqhome.htm.

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Picture 1

Indoor Garage Parking Area

Picture 2

Fresh Air Intake for Office AHU

Picture 3

Break Room in Garage

Picture 4

Example of Exhaust Fan in Ceiling of Garage and Repair Shop

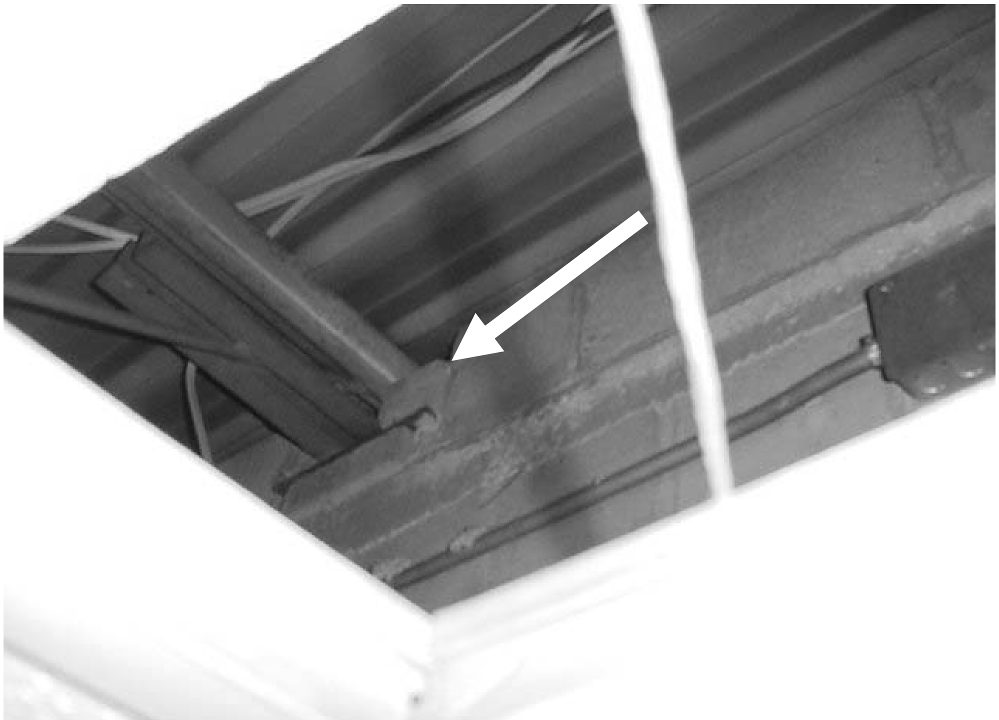
Picture 5

Example of Exhaust Vent on Roof

Picture 6

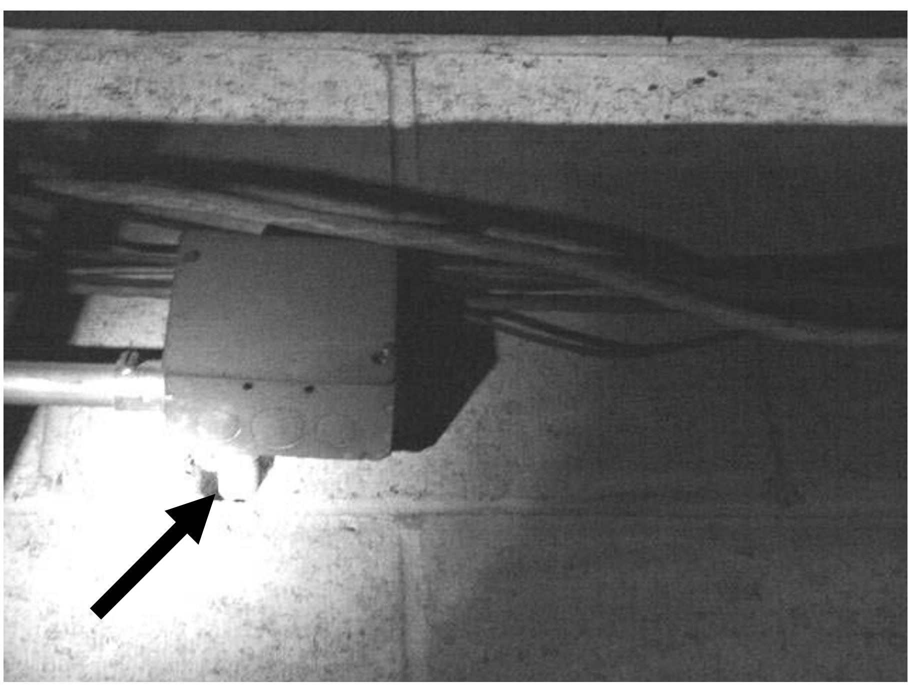
Welding Exhaust Vent

Picture 7



Hole in Wall Shared By Office and Garage above Ceiling on Office Side

Picture 8



Hole in Wall Shared By Office and Garage, Garage Side

Picture 9

Hole in Wall Shared By Office and Garage, Garage Side

Leominster department of Public Works | **Indoor Air Results**

109 Graham St, Leominster, MA | **Date: 1/27/2006**

Table 1

Location	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	PM2.5 ($\mu g/m^3$)	Temp (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Outdoors (Background)	366	ND	9	40	11					
Site plan room	662	ND	9	65	24	0	N	Y	Y	
Engineer's office	736	ND	12	68	20	3	Y	Y	N	3 water damaged ceiling tiles Door open
Main office	614	ND	13	69	17	1	Y	Y	Y	Humidifier Ozone generator
Tyler office	644	ND	14	70	16	1	N	Y	N	
LaPointe office	711	ND	13	72	17	1	Y	Y	N	
Dispatch	814	ND	31	69	19	3	Y	Y	N	Door open
Forestry	764	ND	34	72	19	0	N	Y	N	
Main hall	673	ND	39	70	18	0	N	N	Y	
Break room	1116	ND	218	68	28	0	N	N	N	Door open
Garage north end	745	ND	374	64	28	0	N	N	Y	

*** ppm = parts per million parts of air**
ND = Non-detectable

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

Table 1-1

Leominster department of Public Works | **Indoor Air Results**

109 Graham St, Leominster, MA | **Date: 1/27/2006**

Table 1

Location	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	PM2.5 (µg/m^3)	Temp (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
								Supply	Exhaust	
Garage center	733	ND	372	61	29	0	N	N	Y	
Garage south end	990	2	438	60	31	2	N	N	Y	Truck operating
Repair garage	448	3	498	59	16	3	N	N	Y	Arc welding Outside door open

*** ppm = parts per million parts of air**
ND = Non-detectable

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

Table 1-2